# Quantitative dynamics on stimulating regeneration and sowing seedlings of *Larix gmelinii* in Daxing'an Mountains

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**Abstract:** To understand the quantitative dynamics and death reason of stimulating regeneration seedlings is significant for stimulating the natural regeneration of *Larix gmelinii* and implement of conservation project of natural forest. This paper summarized location observations and directly-seeding simulation experiments of six permanent sample plots that were set up after the seed bumper harvest year of *Larix gmelinii* in 1989. The study showed that stimulating natural regeneration seedlings had a large mortality in the first three years, especially in the first year of seedling emergence. After three years seedlings died less and stepped into the stable regeneration stage. A large number of seedlings died of sunscald as the primary death reason. For those areas of good site conditions and rich soil, damping-off would cause seedlings to death in large quantities. The task of stimulating regeneration is mainly to get rid of the litter (forest floor) on burned areas. By means of promoting measures, emergence rate of sown seeds would be several times and dozens of times higher than that of seed shedding on the condition of retention of forest floor. Promoting the regeneration need to select the suitable site against great slope and low-lying lands; at the same time, be careful of the avoidance of frost heaving by depression water.
**Key words:** *Larix gmelinii*; Larch; Stimulating natural regeneration; Seedlings; Burn area; Daxing'an Mountains.
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## Introduction

*Larix gmelinii* is one of major timber species in the northeast Daxing'an Mountains in China. It plays an important role in providing lumber, maintaining the natural environment in this region and adjusting ecological equilibrium. A large number of burned areas and cut-over areas need to regenerate every year. *Larix gmelinii* has great natural regeneration capability and enough seed sources, and almost meets a bumper harvest year every three years (Xu *et al.* 1992; Shan 1990; Xu *et al.* 1993). Some burned and logged areas would be rapidly restored through a few of assistant measures, therefore, promoting the natural regeneration has been proved to be the significant means for the restoration of forest resources and conservation project of natural forest on those areas. To understand the quantitative dynamics of regeneration seedlings of *Larix gmelinii*, change of survival rate, and the death reason will lead to mastering the technics of promoting natural regeneration and improving regeneration effect. Furthermore, it is vital for rapid restoration of forest vital for rapid restoration of forest resources and implement of conservation project of natural forest. A lot of work about results of natural regeneration or general promoting regeneration has been seen in early documents by reason of the less location study on regeneration quantitative dynamics. This paper makes a summary for the interrelated study, which was carried out in Tuqiang enterprise for technical assistance in Daxing'an Mountains from 1989 to 1994, where a big forest conflagration occurred in 1987. This study revealed the quantitative dynamics laws of regeneration seedling of *Larix gmelinii* through promoting natural regeneration in the permanent observation plots and by direct seeding simulation experiment, and clarified the major factor of seedling death. Hence, it would provide scientific basis for further development of stimulating regeneration of *Larix gmelinii* and successfully performance of the conservation project of natural forest in the days to come.

## Study areas

Study areas are situated on the northern slope of Daxing'an Mountains in northwest Heilongjiang Province (53°34'-52°15' N, 124°05'-122°18' E), which is typical tundra landforms of low mountain range and broad mountain valley and belongs to temperate

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continental climate, with short summer and long winter. Mean temperature is –4.94℃, annual precipitation is 432 mm, and frostless period varies from 82 to 109 d. The main soil types are brown coniferous forests soil (Xiao and Shu 1988), podzolized brown coniferous forests soil, amorphic soil (Xu *et al.* 1992) and marshy soil. The dominant tree species include *Larix gmelini, Pinus sylvestris* var. *mongolica, Batula platyphylla, and Populus davidiana,* and so on. These tree species form various *Larch* forest, *Pinus* forest and secondary *Populus/Betula* forest.

**Study methods**

In 1991, six 2-hm$^2$ permanent sample plots of *Larix gmelini* were founded in the stimulating areas of regeneration year (1990). With consideration of workload, three permanent sample straps were set up in every sample plot. Site types are burned areas with three stimulating ways: artificial preparation, by tractor with board, and by preparation machine. Fifty 4-m$^2$ quadrate were set up in permanent sample strap, for counting regeneration seedlings. The seedlings, which regenerated in 1990 in quadrate, were tagged one by one with serial number, and recorded on squared paper. Survival and dead plants as well as death reason were recorded during investigation period every year, and totally 1 010 seedlings were observed. To find out the number change of seedling emergence and the death reason of small seedling from 1993 to 1994 June, 7 2 m×2 m quadrates were set up in different site types, and directly seeding simulation experiments were conducted with periodical observation and record of number and type of death in various treatment ways. To investigate smoothly, dead seedlings recorded were removed away. Therefore, death number within two observation periods could be accurately written down. To gain a clear idea of the effect of ground cover on emergence and growth of seedlings, three kinds of seeding treatments were carried out in experiments: (i) retention of forest floor and removal of living ground cover; (ii) retention of living ground cover and removal of forest floor (furrow seeding); (iii) non-furrow seeding (comparison). The seed number of treatment ways is 600-1 000 grains, and germination rate was obtained by the germination experiments before seeding. In addition, zonary seeding in holes was conducted, namely, sowing mechanically with 2-3 grains in every distance, to understand the survival states under various conditions.

## Stimulating regeneration seedlings

**Survival rate**

The mean survival rate of the seedlings that emerged in 1990 was 68.6%±6.5% up to 1994, or 31.4% seedlings died in five years, with a mean annual mortality of 6.3%, while three-year regeneration seedlings that emerged in 1992 was 62.3%±14.4%, or 37.7% mortality, with a mean annual mortality of 12.5%, which was 6% higher than the former. As to the change of regeneration frequency; the regeneration frequency of seedlings that emerged in 1990 changed from mean 73.3%±22.7% to 68.7%±25.3%, decreased by 4.6%, or 0.92% per year. But the frequency of seedling emergence from 1990 to 1992 decreased by 8.1% or 2.7% per year. The latter is 1.9% more than the former (Fig1). Comparison to the survival rate of plant number, the change of regeneration frequency is very less. This indicated that the change of frequency is more stable, which is obviously related to mean number of seedlings, the more seedlings in sample, the less effect of the death of seedlings on frequency change.

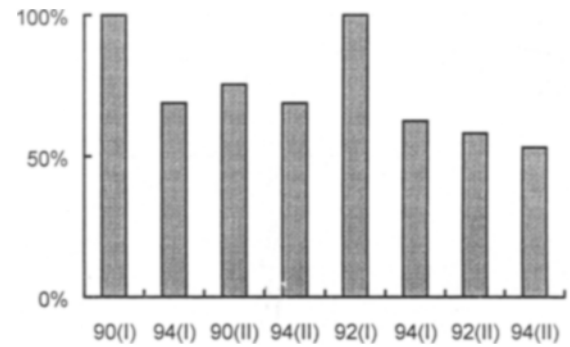


**Fig.1 Seedling survival rate and change of regeneration frequency of *Larix gmelinii***

Ⅰ. Seedling survival rate, Ⅱ. Change of regeneration frequency

**Relationship between seedling number and ages**

Seedling quantitative dynamics of *Larix gmelinii* varied with seedling age. Seedling number would come to maximum in regeneration year. With increasing of seedling age and self-thinning, the amount of seedlings was decreased gradually.

As shown in Fig 2, no matter the seedlings regenerated in 1990 or in 1992, the seedling number will decreased gradually with increasing of age. 23.1%-33.5% of seedlings died in the first year of regeneration (according to regeneration year), up to the fifth year, the mortality of seedling is only 1.0% (Table 1).

**Death peak and stable stage of regeneration seedlings**

Since only in the stable period of regeneration, can it be determined if the young forest has formed, and whether other measures of management and tending treatments should be taken. The mortality of regenerated seedling came to the summit in the first 1-2 year, particular in the first year of regeneration, but

the regenerated seedlings entered stable period after three years (Table 1).

**Table 1. Mortality of regeneration seedlings of *Larix gmelinii* at different age /%**

| Regeneration year | Mortality of seedling | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-yr-old | | 2-yr-old | | 3-yr-old | | 4-yr-old | | 5-yr-old | |
| | Average | SD. | Average | SD. | Average | SD. | Average | SD. | Average | SD. |
| 1990 | 23.1 | ±2.7 | 5.2 | ±3.8 | 9.8 | ±1.9 | 1.2 | ±0.4 | 1 | ±0.6 |
| 1992 | 33.5 | ±13.9 | 8.6 | ±3.0 | 5.8 | ±1.1 | | | | |

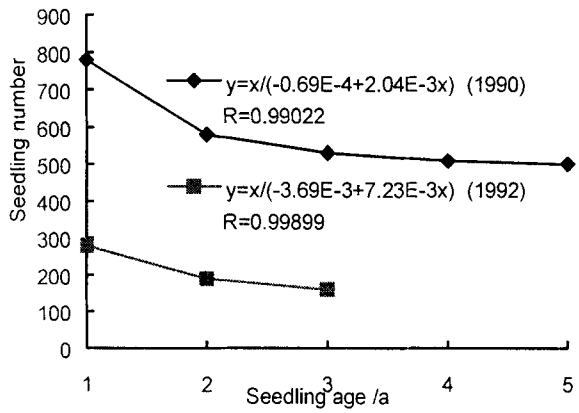


**Fig.2 Correlation between number and age for *Larix gmelinii* seedlings**

## Seedling mortality and site conditions

The change of seedling mortality of *Larix gmelinii* is great related to site conditions. The mortality of seedlings on the site of abrupt slope *Rhododendron duaricum/Larix gmelini* forest was the largest as a result of sunny slope with strong sunshine, thin soil, and aridity easily suffering form drought and sunscald (Table 2), followed by on the site of mild slope *Vaccinium vitis-idaea/Larix gmelini* forest, and the smallest was on the level land. From Table 2, we can see that there was an obvious difference in seedling mortality between the two regeneration years, even in the same site type. The mortality of the seedlings regenerated in 1992 was bigger than that of the seedlings regenerated in 1990, which was resulted from the different climate.

**Table 2. Death rate of regeneration seedling in different site types & different seedling ages /%**

| Year | Topography and slope degree | Forest type | Mortality of seedlings | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1-yr-old | 2-yr-old | 3-yr-old | 4-yr-old | 5-yr-old |
| 1990 | Level land | Moss *Vaccinium vitis-idaea/Larix* forest | 20.04 | 1.39 | 2.70 | 1.11 | 0.84 |
| | Mild Slope 5-10° | *Vaccinium vitis-idaea/Larix* forest | 24.71 | 6.77 | 5.59 | 1.18 | 1.19 |
| 1992 | Level land | Moss *Vaccinium vitis-idaea/Larix* forest | 22.00 | 10.26 | 7.14 | | |
| | Mild Slope 5-10° | *Vaccinium vitis-idaea/Larix* forest | 43.01 | 8.49 | 7.22 | | |
| 1990 | Abrupt slope 27° | *Rhododendron duaricum/Larix gmelini* forest | 76.80 | | | | |

## Effect of preparation ways on regeneration seedlings

Three kinds of site preparation ways were investigated to identify the effect of stimulating way on seedling death: (1) Soil preparation by tractor with board is to use turned-over board on back of tractor to push soil in moving back. (2) Soil preparation by tractor with frame is to use four-leg iron frame drawn by a tractor to plough a furrow of 35 cm wide and 10 cm deep. (3) Soil preparation machine that is composed of two disc harrows and drown by 50-H tractor to plough a furrow of 35-40 cm wide and about 10 cm deep.

The seedlings on which different preparations were performed in 1989 were investigated in 1990 and 1991 (Table 3). In the first regeneration year, the mortality of seedlings by tractor with board preparation was very similar to that by soil preparation machine. From Table 3, we can see that on the level land of *moss-Vaccinium vitis-idaea-Larix gmelini* forest, mortality of seedlings by tractor with frame preparation was higher, with a maximum mortality 51,2%. This assistant method had very bad effect on conservation of regeneration seedlings. Because this soil preparation only plough a row and expose the topsoil, weed, especially *Deyeuxia angustifolia*, would rapidly resume growing luxuriantly and bully the seedling to death.

## Mortality of seedling in growth season and non-growth season

Mortality of the seedlings regenerated in 1992 was investigated in growth season (from May to September) and non-growth season (from October to the next May) during 1992-1994 (Table 4).

After emergence (1992), the mortality of seedling in growth season was 3.4% higher than that of non-grown season. To the next year (1993), seedling mortality decreased rapidly both in the growth season and non-growth season, at the same time, the

death number in two seasons tends to the same with an averaged mortality of 6% (Table 4).

**Table 3. Mortality of seedling with the different ways of soil preparation**

| Plot No | Preparation ways | Topography | Forest type | Investigation year | Regeneration frequency | Seeding number per ha | Mortality / % |
|---|---|---|---|---|---|---|---|
| 1 | Tractor with frame | Level land | *Moss- Vaccinium vitis-idaea/Larix forest* | 1990 | 100.0 | 5433 | 51.2 |
| | | | | 1991 | 90.0 | 2657 | |
| 2 | Tractor with broad | Mild slope | *Vaccinium vitis-idaea/Larix forest* | 1990 | 82.0 | 2063 | 24.9 |
| | | | | 1991 | 80.0 | 1550 | |
| 3 | Tractor with broad | Level land | *Moss- Vaccinium vitis-idaea/Larix forest* | 1990 | 94.0 | 5863 | 20.1 |
| | | | | | 92.0 | 4688 | |
| 4 | Preparation machine | Level land | *Moss- Vaccinium vitis-idaea/Larix forest* | 1990 | 74.0 | 1779 | 23.9 |
| | | | | 1991 | 79.2 | 1354 | |
| 5 | Preparation machine | Mild slope | *Vaccinium vitis-idaea/Larix forest* | 1990 | 50.0 | 1125 | 24.4 |
| | | | | 1991 | 48.0 | 85 | |

**Table 4. Mortality of *Larix gmelinii* seedlings in grown and non-grown season /%**

| Sample plot | Season | Mortality /% | | |
|---|---|---|---|---|
| | | 1992 | 1993 | 1994 |
| No.4 | Growth | 14.55 | 2.50 | 18.4 |
| | Non-growth | 12.73 | 2.50 | |
| No.5 | Growth | 14.00 | 4.88 | 4.20 |
| | Non-growth | 4.0 | 8.54 | |
| No.6 | Growth | 21.37 | 9.46 | 3.20 |
| | Non-growth | 22.14 | 6.76 | |
| Average | Growth | 17.48 | 6.12 | 7.0 |
| | Non-growth | 13.99 | 6.63 | |

### Death pattern of stimulating regeneration seedlings

According to the location observations in six permanent sample plots (No.1-6), totally 158 regeneration seedlings died in three years. About 80% of seedlings died of frost heaving and 10% died of drought. Other death reasons caused about 10% mortality, including damping-off, soaked to death in low-lying land or puddle, and lack of water by wind dryness owing to growing on the rock with very thin soil or leftovers from felling, and so on (Fig. 3). Those death types tend to the same in the 3-4 year old seedlings.

## Sowing seedlings

### Amounts of emergence in different site and sowing years

The emergence rate of *larix gmelinii* (amounts of emergence at investigating time/ seeding-quantity ×germination percentage) is related to sowing year and site. The emergence rate of sowing seedling reached 96.1% on the level area at downhill shaded by small trees, where was the site of *Grass-Larix gmelini* forest before burning, followed by on middle-hill (73.8%), where was the site of *Ledum palustre/Pinus sylvestris* var. *mongolica/Larix gmelini* forest before burning, and the lowest emergence rate (40%) appeared on abrupt slope of top-hill, where was the site of *Rhododendron dahuricum/Pinus sylvestris* var. *mongolica/Larix gmelini* forest and *Lespedeza froribunda/Rhododendron dahuricum/Pinus sylvestris* var. *mongolica/Larix gmelini* forest.

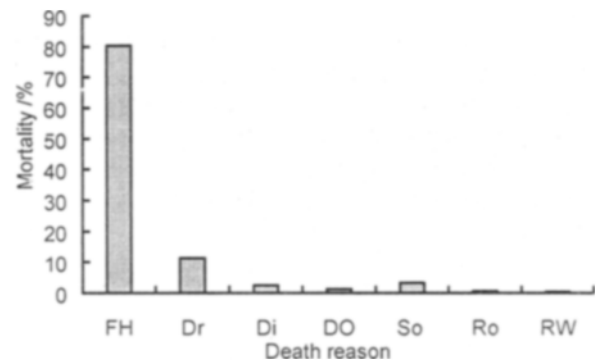


**Fig. 3 Distribution of wild seedling of *Larix gmelinii* in accordance with death reason**

FH: frost heaving; Dr: drought; Di: disappear; DO: damping –off; So: soaked; Ro: on the rock; RW: on the rotted wood.

As to emergence of seedlings sown in different years, seedlings emerged at the end of May 1993 achieve the best emergence rate. The result of direct seeding simulation experiment, in early June 1994, turned out unsatisfying. About 64% experiment fields did not emerge, and emergence rate of few sowing fields (about 20%) come to 30%~40%. Seed cannot sprout well because of lack of water caused by high air temperature and extreme soil aridity in June & July in this year.

### Emergence period

Seeds of *Larix gmelinii* usually come out of the ground in a short time. Emergence varies with site conditions from two to ten days. Seed sprout slowly

in the low terrain with low ground temperature, where emergence period lasts for 8-10 d.

**Effects of treatment ways on emergence**

Emergence number is related closely with the treatments of experiment fields. Generally, the number of emergence by furrowing sowing and hole sowing with wood stick were ten or even dozens times that of control area where the ground cover was not removed. Ground cover, particular the existence of forest floor (litter), would separate the seed from the soil (Tao 1989). Furrowing sowing and hole sowing could make seeds directly fall into the soil.

**Survival rate of small seedlings**

Survival rate of small seedlings varies with site conditions and sowing year. The survival rate of seedling was 60.7% in the first sowing year (1993), and drop down 48.1% to the next year (1994) in No.1 experimental small area, while that of seedlings sown in 1994 was only 2.5% in the same year, because of dry climates, in No.2 experimental area which has same site condition with No.1. Small seedlings in No.6-2 experimental area as low terrain had high survival rate because of good water condition. The survival rates of seedlings on other types of site were very low for the weak capability of moisture conservation of the soil and scorching climate. The emerged seedlings on 75% experimental areas all have died out in same September.

As for the death process of small seedlings, the mortality was high in early period of emergence. This indicates that death process was short, generally lasted about ten days and the mortality declined soon afterwards. The death process of small seedlings on low-lying and level lands was slight short, while that on sunny and large degree of slope areas was little long.

It should be pointed out that living ground cover has positive effect on the survival rate of small seedlings, for example, on the same site condition, the survival rate of the small seedlings by furrowy sowing with ground cover was higher than that of seedlings sown by removing living ground cover. In addition, we found that the death process of small seedlings in the control area with retention of ground cover, such as *Carex ussuriensis*, *Sanguisorba sitchensis*, was longer than that in experimental area with removing living ground cover.

We carried out the experiment of hole sowing in every distance in 1993. The survival number of seedlings on different sites and treatments was shown in Fig. 4. On the site of *Ledum palustre/Larix gmelini* forest on mild slope without wild weed the survival rate of seedlings was 4%, while that on the same site with wild weed was 23.5%. On the site with *Rhododendron dauricum* the survival rate of seedlings was 27.6%. On the site with soil preparation and shaded by *Rhododendron dauricum* the survival rate of seedlings was 43.8%. This proved the existence of weed and shrub is advantage to survivals of seedlings. The highest survival rate of small seedlings occurs on the site with soil preparation and shaded by *Rhododendron dauricum*.

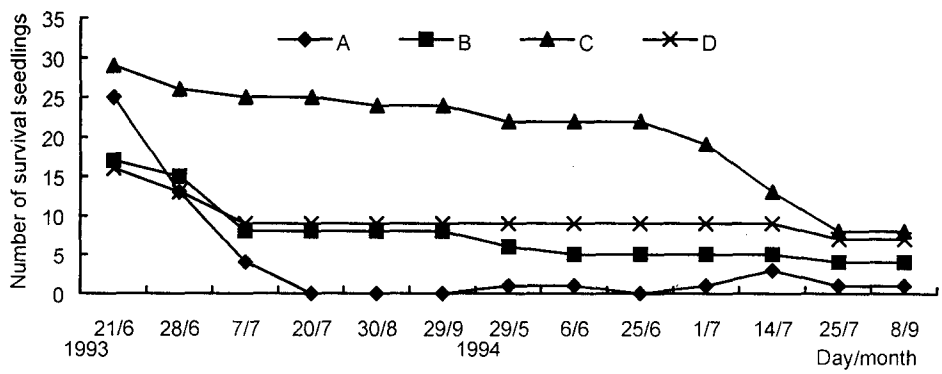


**Fig. 4 The survival situation of sowing seedlings of *Larix gmelinii* under different site conditions**

A: without grass; B: with grass: C: with shade of *Rhododendron* and soil preparation; D: under *Rhododendron*

**Death types of sowing seedlings**

Death types of small seedlings vary with site types and seedling age. Sunscald was the major factor of death of sowing seedlings, which took up 74.6% of total 1 060 death seedlings, followed by damping-off, which accounts for 18.7%, and drought was the third factor of death, accounting for 5.1%. Other factors of death include bird harm, damage by man and so on. It's necessary to point out that damping-off does not occur commonly, and it mainly occurs in the low area with damp and fertile soil but poor ventilation. Sunscald mainly occurs on the hillside (see table 5). From the later period of first growing season to the next year, sunscald had decreased remarkably. In

growth season, on the hill slope, the effect reason for death of sowing seedlings in the later period much related to drought.

**Table 5. Death pattern of sowing seedling of *Larix gmelinii* in 1993 and 1994**

| Sowing time | Death type | | | | | Total |
|---|---|---|---|---|---|---|
| | Damping-off | Sun-scald | Bird | Sup-pressed | Drought | |
| 1993/5 | 198 | 688 | 10 | 7 | 54 | 957 |
| 1994/4 | 0 | 103 | 0 | 0 | 0 | 103 |
| Total | 198 | 791 | 10 | 7 | 54 | 1060 |
| % | 18.7 | 74.6 | 0.9 | 0.7 | 5.1 | 100.0 |

The research on how high air temperature and ground temperature could cause sunscald was not done in this study. Some records of ground temperature observed in 1994 for seed spots were shown in Table 6. Ground temperature is different with site types. For example, the ground temperature measured at a.m. 10:00, July 14, 1994, for level land (Plot No.1), it was 37℃, but for sunny top-hill (Plot No.4) it was up to 53.3℃. The just emerged seedlings are easily scorched on base stem by hot ground on top-hill. The ground temperature of the site with living ground cover or shaded by *Rhododenron dahuricum* shrub was much lower than that of the site without shading, so the seedlings on this site are unlikely suffered from sunscald. The areas of sunny abrupt slope, with dry soil, are unsuitable for stimulating regeneration of *Larix gmelinii*.

**Table 6. Ground temperature (℃) observed in 1994**

| Observation time | | | | Sample plot | | | | Ground temperature In nursery** |
|---|---|---|---|---|---|---|---|---|
| Year | Moon | Day | Time | No.2 | No.3 | No.4 | No.3* | |
| 1994 | 7 | 14 | 10:00 | 37.0℃ | 51.5℃ | 53.5℃ | 42.5 ℃ | 42.5℃ |
| | | | 14:30 | 40.3℃ | 44.8℃ | | 43.8℃ | |
| | | 15 | 14:30 | 47.7℃ | 51.8℃ | | 48.8℃ | 48.0℃ |
| | | 17 | 09:00 | 39.0℃ | 52.0℃ | | 47.0℃ | 52.5℃ |

*: Under Rhododendron; **:Data from the meteorological observation material of nursery in Tuqiang

## Conclusions and suggestions

Sowing simulation experiments showed that germination and seedling growth of *Larix gmelinii* are evidently affected by environmental factors and site conditions. On the site in low terrain with good water condition the emergence rate is high and the seedling unlikely suffers from sunscalds.

The main factor affecting semination and emergence is the existence of dead forest floor, which restrains seeds to touch soil. Hence, the first assistant measures for stimulating regeneration are to clear litter out and uncover the topsoil.

Stimulating regeneration seedlings present fast natural thinning, particularly for ten-day old seedlings. The relationship between seedling number (y) and seedling age (x) can be expressed as y=x/(-A+Bx). The seedling number decreased sharply in the first year of regeneration and come to be stable after three years.

Frost heaving, as the main death reasons of stimulating regeneration seedlings, usually occurs on the low-lying land with too much water or in some pothole resulted from improper soil preparation. So, the proper way of soil preparation in such places is to get rid of divot and to avoid forming pothole.

Directly seeding simulation experiment proved that removing litter and uncovering soil could raise seed emergence rate and improved natural regeneration So, stimulating natural regeneration is a valid measures to restore the forest resource of *Larix gmenilii*, and an important way for conservation of natural resources.

It is better to remove the slash on cutting areas and create good condition for natural regeneration of seedlings.

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